

# Air Force Power Requirements

January 24, 2006



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**Propulsion Directorate**  
**Air Force Research Laboratory**

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>24 JAN 2006</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2006 to 00-00-2006</b>	
4. TITLE AND SUBTITLE <b>Air Force Power Requirements</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Air Force Research Laboratory,Power Division,Propulsion Directorate,Wright Patterson AFB,OH,45433</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>22</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			



# Outline



- Our Recent Heritage – MEA



- Our Plan – HiPAC



- HiPAC Technologies

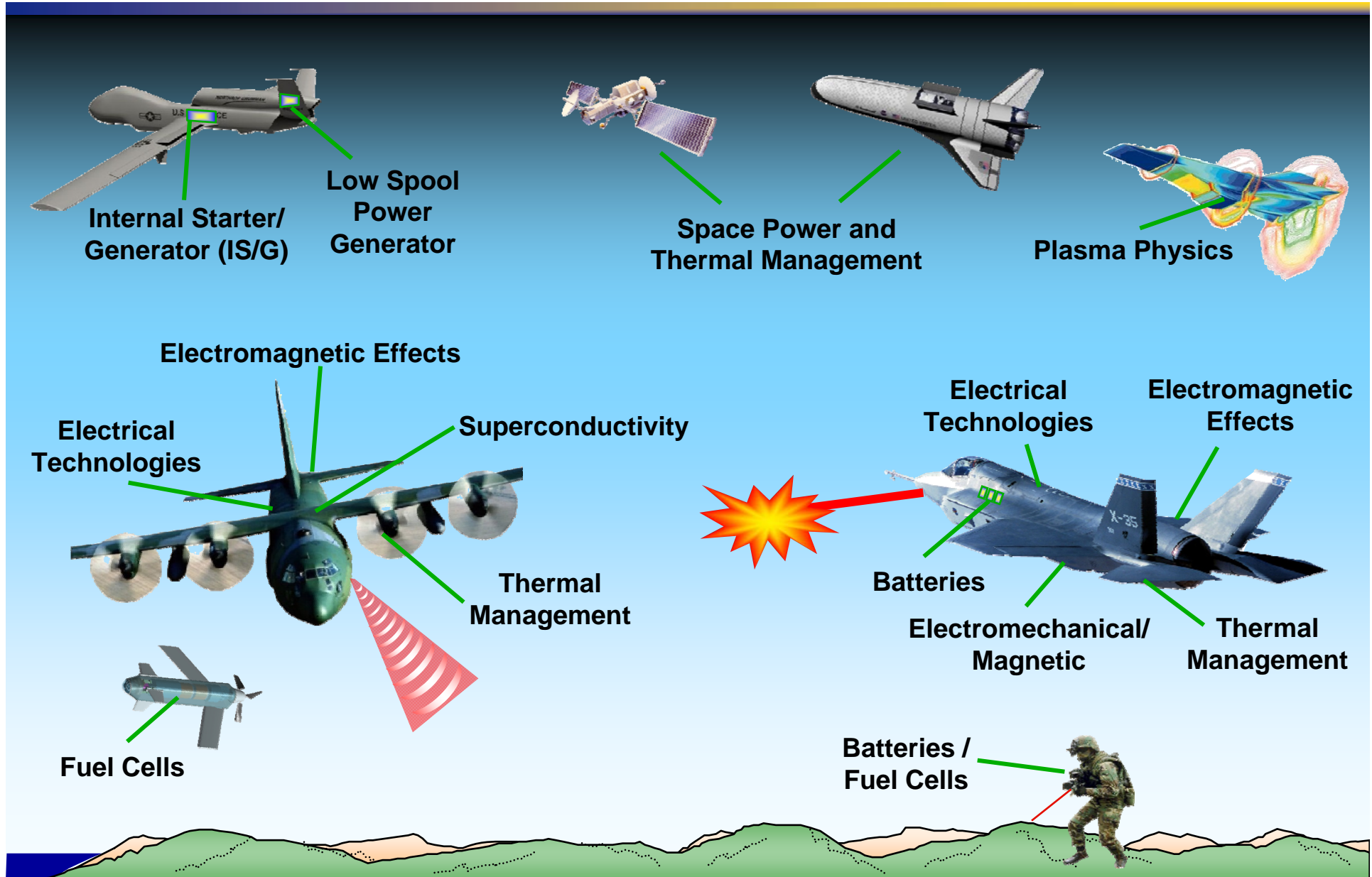


- Summary

*Powering the United States Air Force*



# Air Force Research Lab Power Technology Program





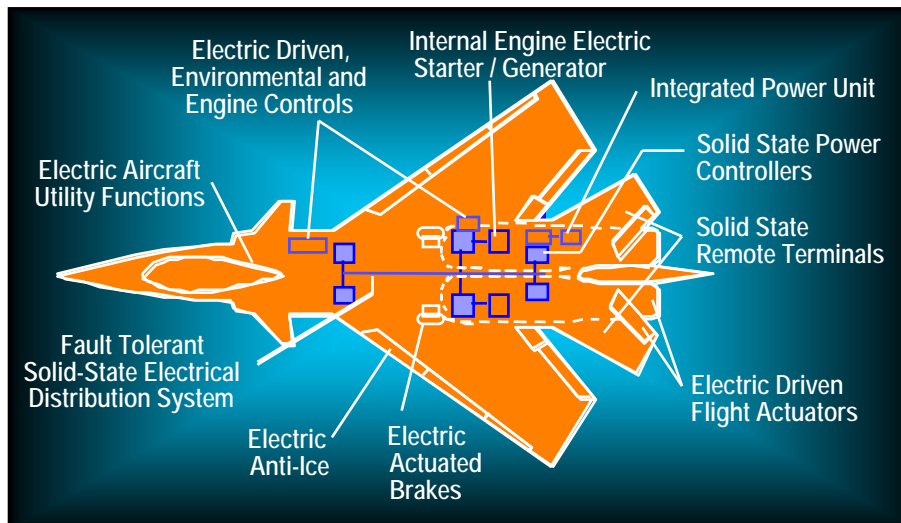
# Our History: The More Electric Aircraft



## THE VISION



## THE IMPACT



**All-electric aircraft eliminates complex, inefficient, maintenance intensive...**

- Hydraulics
- Bleed Air Pneumatics
- Mechanical (gearbox) Subsystems

**Savings in \$B's with improved warfighting**

**Enables mission available power for lethal airborne directed energy weapon**



# MEA Generation I Concept Transition to Lockheed F-35

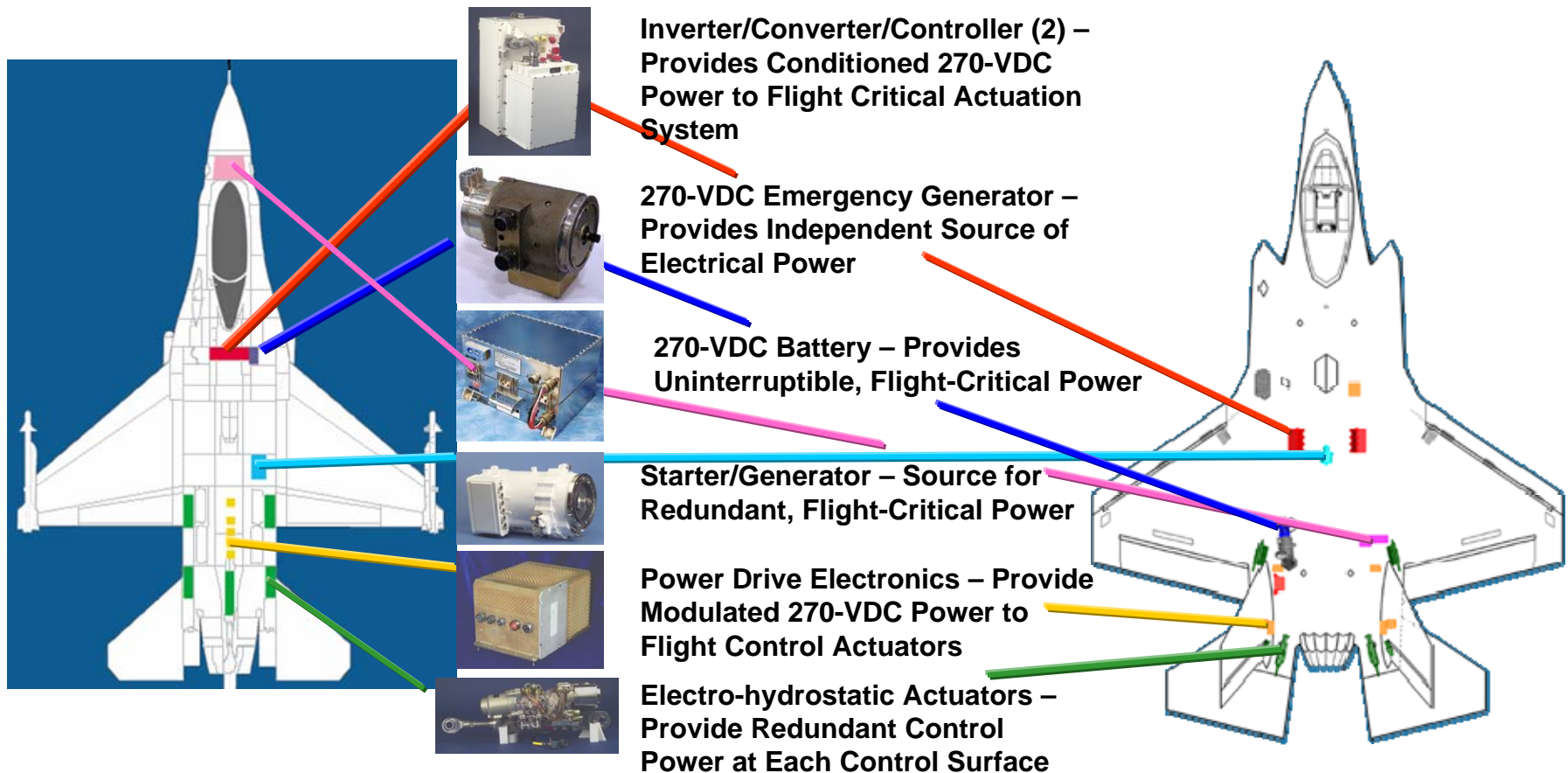


## Affordable, High-Performance Baseline for F-35

*AFTI/F-16 Demonstration Validates  
More-Electric Aircraft Technologies*

### Common Components

*F-35 Subsystems Suite  
Identical to J/IST*



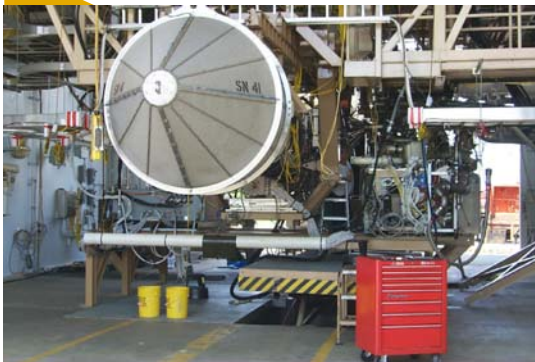


# From Vision to Reality



## F-35 IS THE FIRST TRULY “MORE ELECTRIC” AIRPLANE

- Electric Engine Start
- Electric Power & Thermal Mgt System
- Electric Flight Control Actuation
- Electric Flight Control Power Systems



**Electric Engine Start Ground Demo**

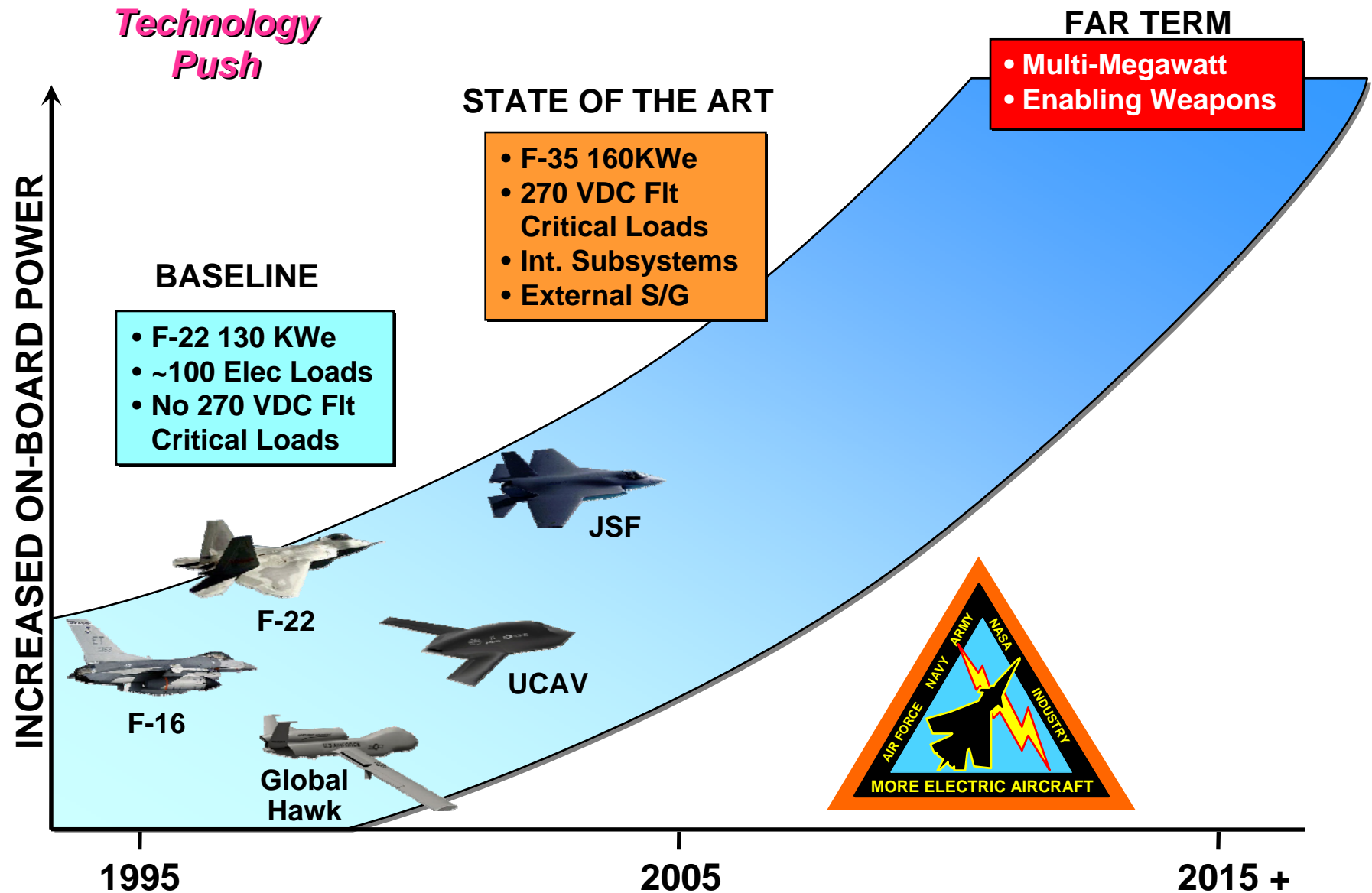
**Starter/Generator / Electric Flight  
Control Actuation Flight Demo**



**MEA Thrust Initiated In 1987**

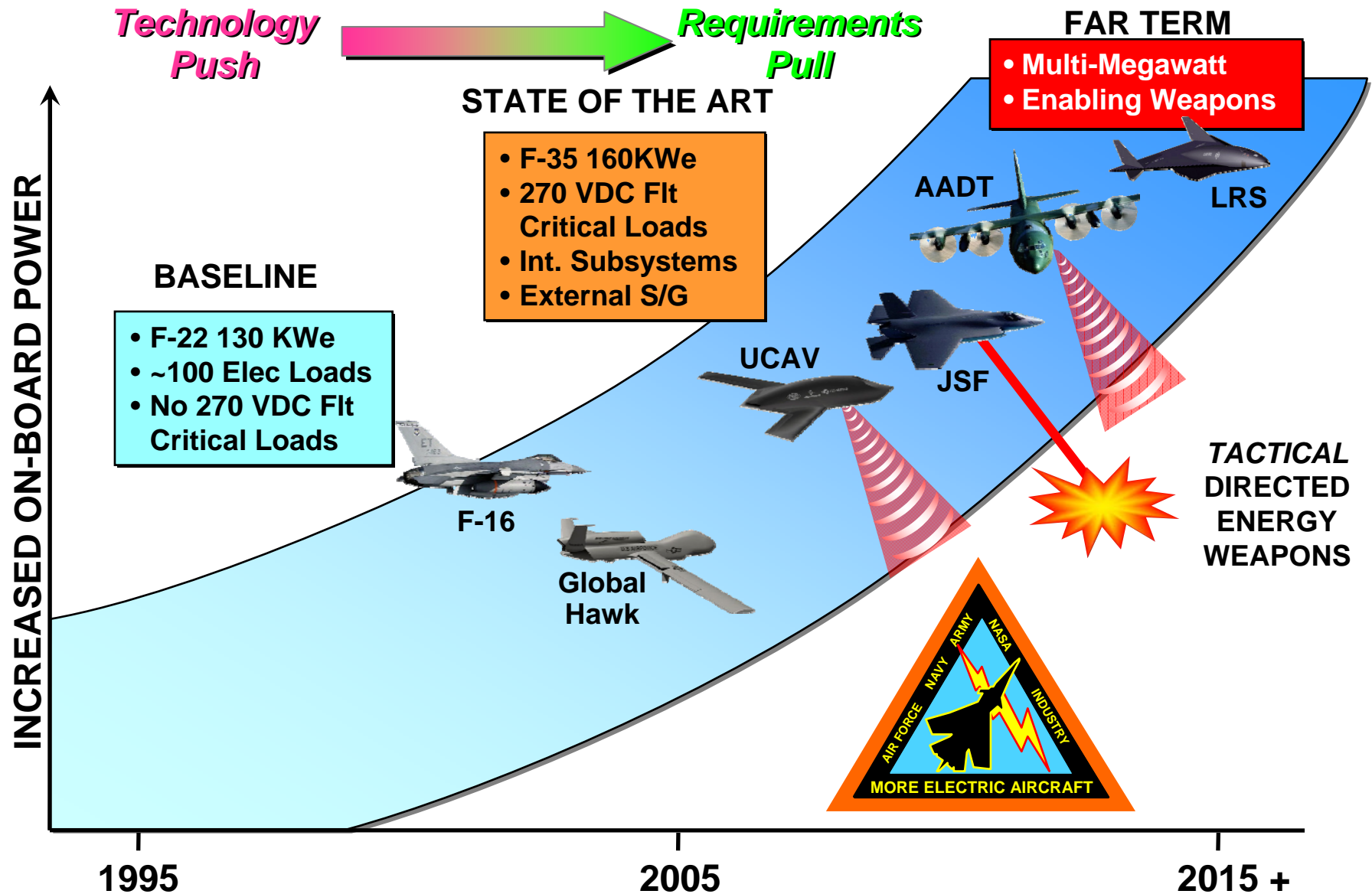


# Exponential Growth for Power and Thermal Technology



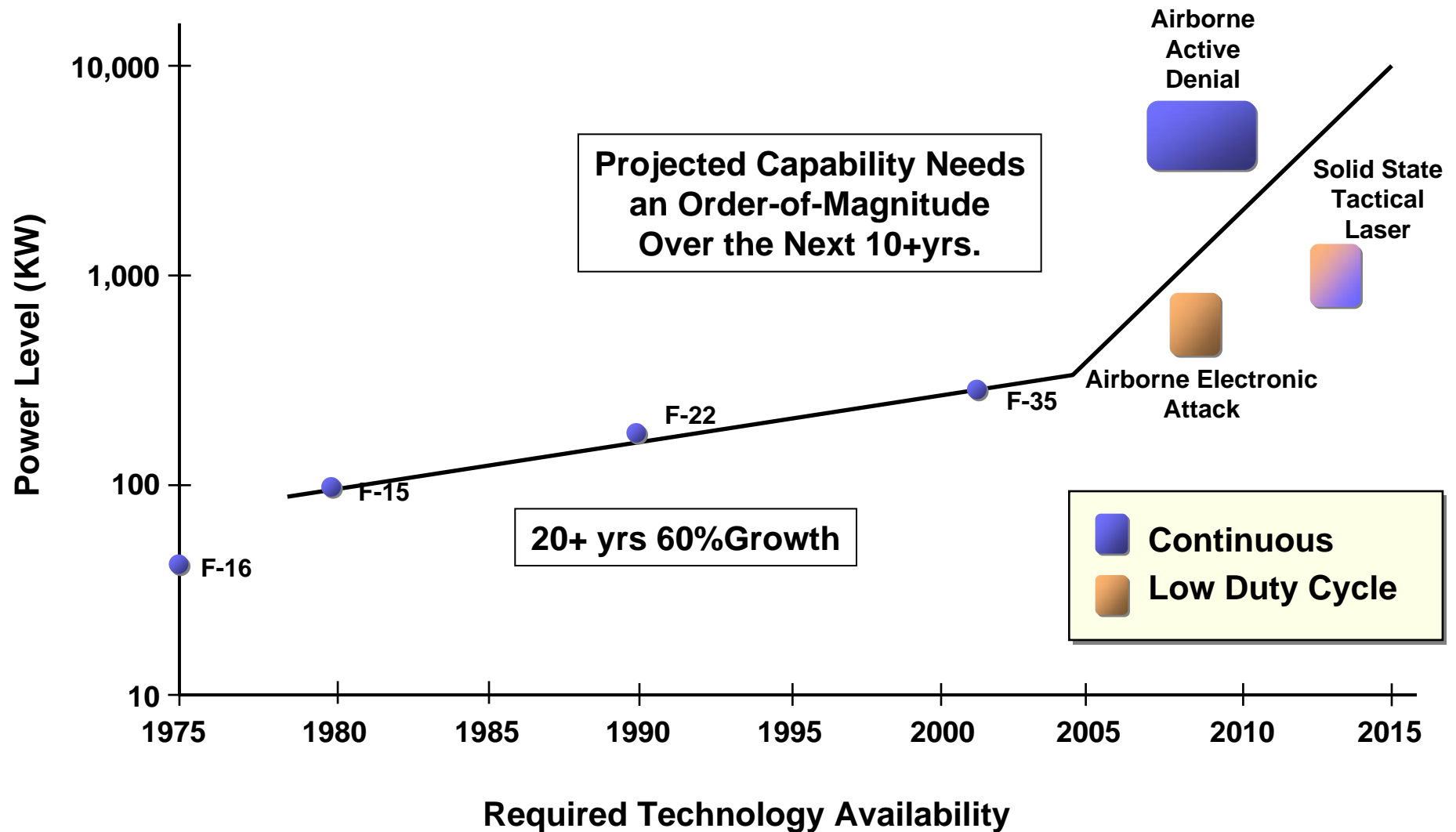


# Exponential Growth for Power and Thermal Technology





# DE Weapons Need Unprecedented Power & Thermal Management





# HiPAC Technical Program Areas



**Micro-Mini  
Platforms**

**Munitions /  
UAV**

**Tactical  
Aircraft**

**Large  
Platforms**

**Directed  
Energy**

- **High Temperature Power System Components**
- **High Temperature Thermal Control Systems**
- **EMI Immunity**
- **Integrated Engine / Power Extraction**
- **Smart Power: Prognostics & Health Management**
- **MW Power Generation**
- **MMW Power Generation**
- **Active High Flux Thermal Control System**
- **Lightweight Compact Power Conditioning**
- **Energy Storage**
- **Electrochemical Power Generation**
- **MEMS Power Generation**
- **MEMS Thermal Management**
- **Pulse Power Components**
- **Subsystem Integration**

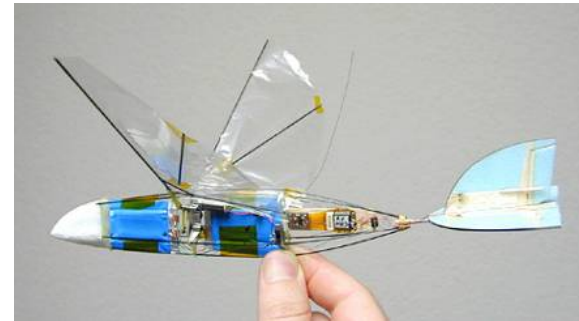


# Micro-Mini Platforms



CAPABILITY FOCUSED

**Small Platforms with sub kW  
Power Requirements**



**Technologies:**

- **MEMS Power Generation**
- **MEMS Thermal Management**
- **Batteries**
- **Fuel Cells**



**TECHNOLOGY ENABLED**

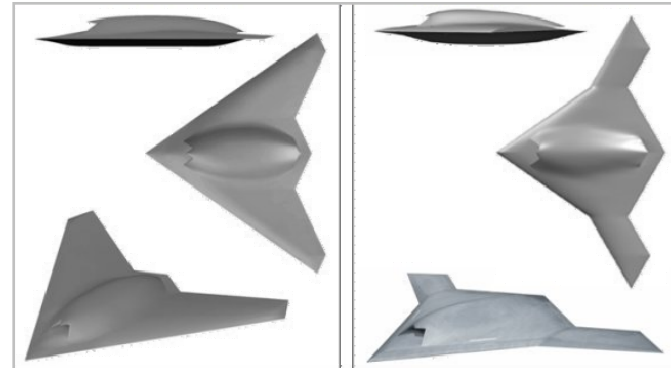
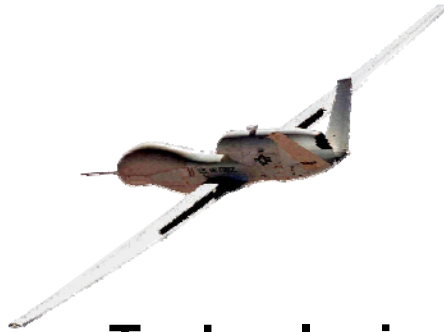


# Munitions / Small UAVs



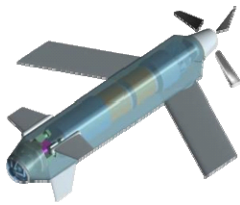
CAPABILITY FOCUSED

**Munitions / Small UAVs with  
1-100 kW Power Requirements**



## **Technologies:**

- EMI Immunity
- Integrated Engine / Power Extraction
- Smart Power – Prognostics and Health Management
- Electrochemical Power Generation
- Light Compact Power Conditioning
- Energy Storage



TECHNOLOGY ENABLED



# Low Spool Generator for Global Hawk



**Enables Advanced Sensor  
Upgrades for Global Hawk**

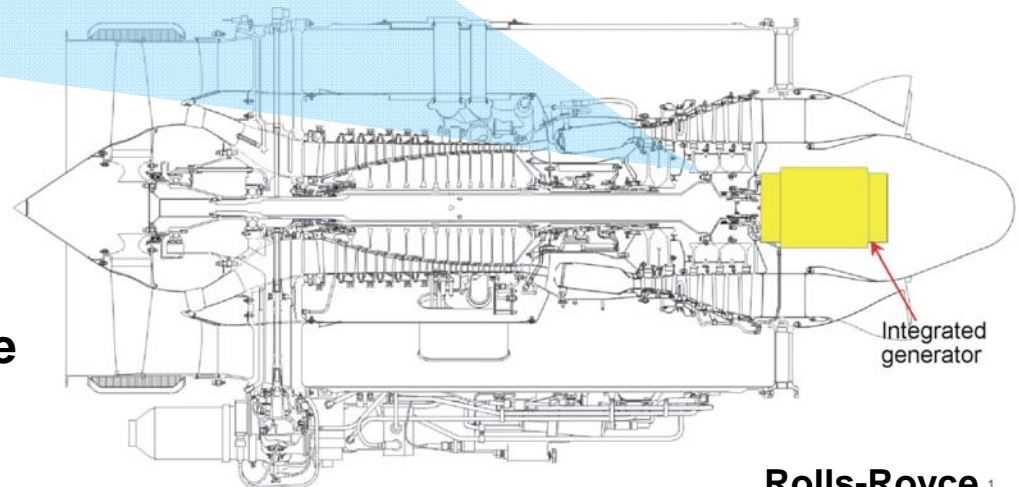
## Power Technologies Benefits :

- 15% Thrust Improvement at Altitude
- 7.5X Increase in Power Generated

## GLOBAL HAWK CAPABILITIES

<b>NOW:</b>	2000 lb Payload 24 Hour on Station 1200 NM range/ 60K ft altitude 10 KVA Payload Power
<b>FUTURE:</b>	3000lb Payload 20 Hour on Station 1200 NM range/ 60K ft altitude hold 25 KVA(Near-term); 75 KVA(Far-term)

## AE3007 ENGINE - GLOBAL HAWK PROPULSION



Rolls-Royce<sup>1</sup>



# Tactical Aircraft



CAPABILITY FOCUSED

## Tactical Aircraft with 100-500 kW Power Requirements



### Technologies:

- High Temperature Power System Components
- High Temperature Thermal Control Systems
- Energy Storage
- Integrated Engine / Power Extraction
- EMI Immunity
- Smart Power: Prognostics & Health Management
- Lightweight Compact Power Conditioning
- Electrochemical Power Generation



TECHNOLOGY ENABLED



# Li Ion Battery



- Lithium Ion Technology Developed Under Joint AFRL/NASA/JPL Program Transitioned to B-2, F-35, and Mars Rovers



- B-2 Batteries >350 Flight Test Hours Logged
- Mars Rover Batteries Fully Operational After 7 Month Cruise Through Space





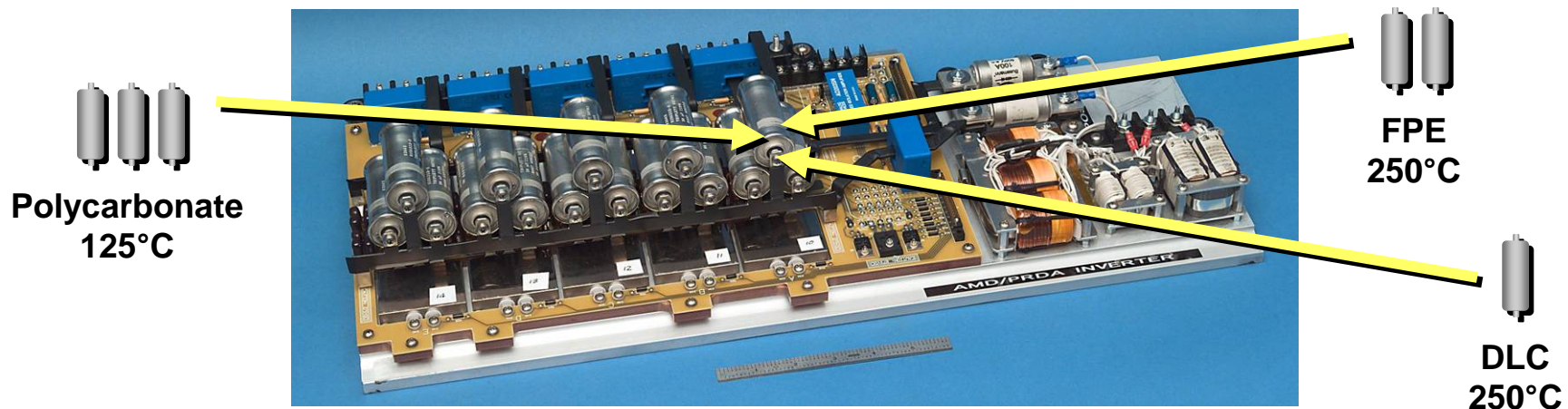
# Revolutionary Capacitor Development



DIELECTRIC	DIELECTRIC CONSTANT	FILM THICKNESS	BREAKDOWN STRENGTH	UPPER-LIMIT TEMPERATURE	ENERGY DENSITY
POLYCARBONATE	3.2	3 m	5 KV/mil	125°C	> 1.0 J/g
FLUORENE POLYESTER (FPE)	3.4	3 m	10 KV/mil	250°C	> 2.0 J/g
DIAMOND-LIKE CARBON (DLC)	3.5	0.5 m	25 KV/mil	250°C	> 4.0 J/g

- Low cost DLC thin film in-house process scale-up (Mar 01); Commercialization by FY04 (energy density)

- Enables DEW - - 2X increase in energy density
- Reduces size, weight & volume





# Large Platforms



**CAPABILITY FOCUSED**

**Large Platforms with  
250 kW - 2+ MW Power  
Requirements**



## **Technologies:**

- **MW-MMW Power Generation**
- **Integrated Engine / Power Extraction**
- **High Temperature Power System Components**
- **High Temperature Thermal Control Systems**
- **EMI Immunity**
- **Smart Power: Prognostics & Health Management**
- **Lightweight Compact Power Conditioning**
- **Energy Storage**
- **Electrochemical Power Generation**

**TECHNOLOGY ENABLED**

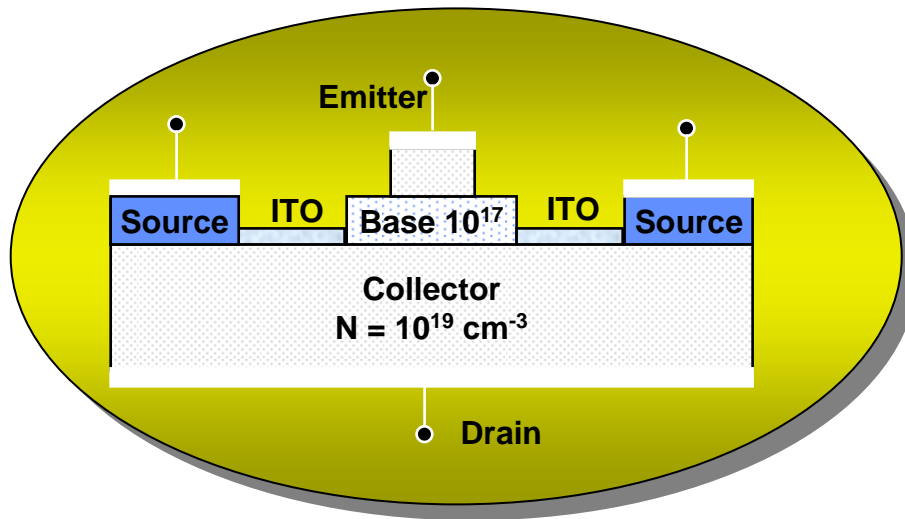


# Optically Triggered SiC Switch



## TECHNICAL CHALLENGES:

Device design is foundational.  
Carrier transport and optical generation not quantified.



## APPROACH:

- Develop key fabrication components
  - SiC photo-transistors (600V, 60-150A)
  - SiC “PGBT”-based switches
  - 2-D modeling in parallel with fab.
- Demo devices in electric actuator drive controllers or I-H motor drive

## OBJECTIVE & PAYOFF:

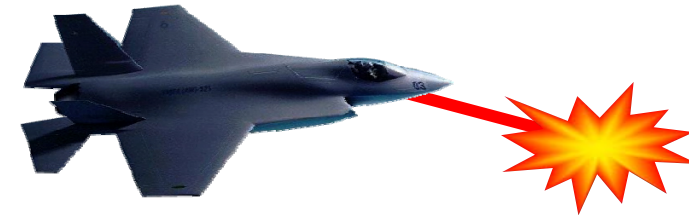
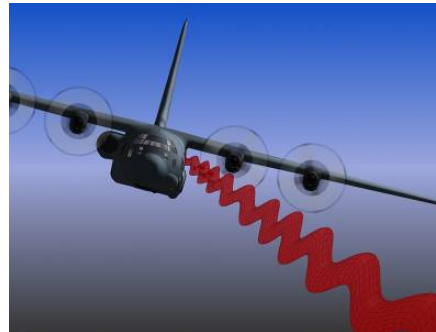
Reduce actuator weight while providing photonic switching device to satisfy the robust actuator switching requirements for an EMI invulnerable FBL/PBW airframe concept.



# Directed Energy



## Directed Energy Concepts with 250 kW - MMW Power Requirements



### Technologies:

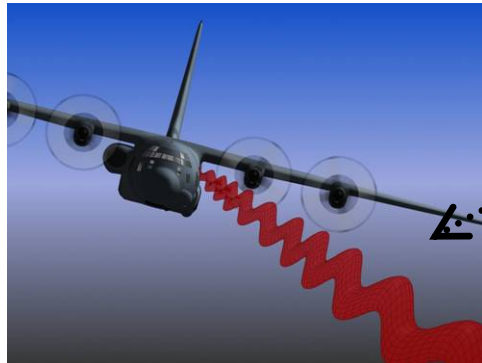
- Integrated Engine / Power Extraction
- MW-MMW Power Generation
- Active High Flux Thermal Control System
- Lightweight Compact Power Conditioning
- Energy Storage
- Pulse Power Components
- EMI Immunity
- High Temp. Power System Comp.
- High Temperature Thermal Control Systems
- Smart Power: Prognostics & Health Management

CAPABILITY FOCUSED

TECHNOLOGY ENABLED



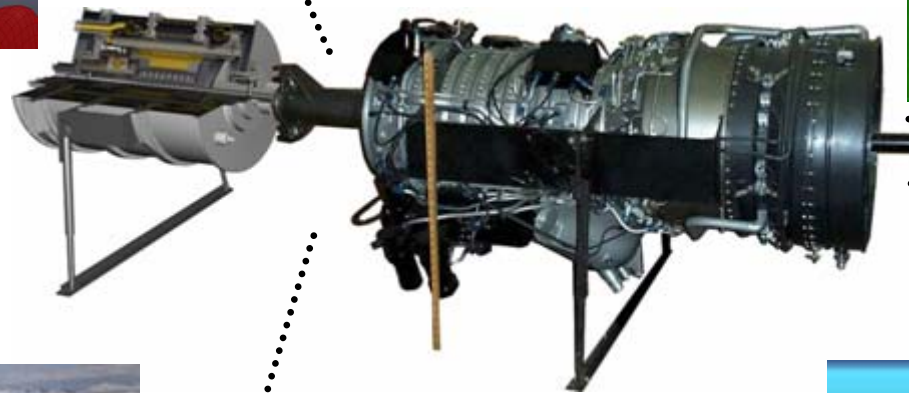
# Multimegawatt Electric Power System



Directed Energy Weapons

**1-5 MW Capability Needed for Multiple Applications**

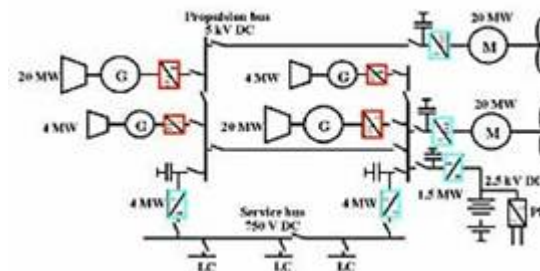
**Army Future Combat Systems Electric Weapons**



**Navy Distributed Power**



**E-10A**

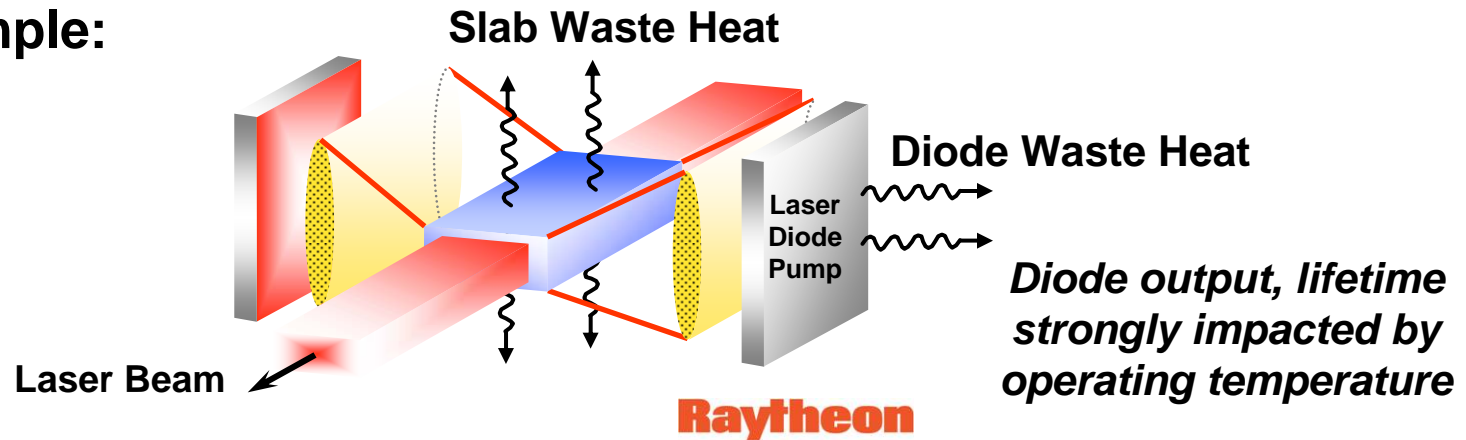




# Power & Thermal Management ... Critical to DEW System Success

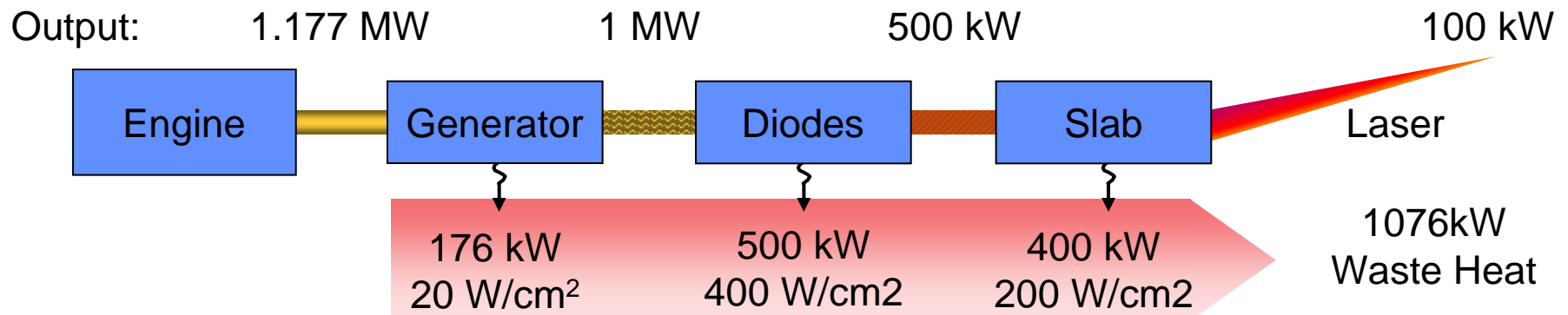


## HEL Example:



The overall efficiency of solid state lasers vary from 10% to 30%, thus large amounts of waste heat must be managed

- As an example, for a 10% efficient laser





# High Power for Aircraft Initiative



*Five Power Regimes from  
Watts to Multi-Megawatts*

*Meet Today's  
and Tomorrow's  
Need for  
Unprecedented  
Power and  
Thermal  
Management*



*System  
Approach to  
Integrated and  
Optimized  
Weapons Power  
and Thermal  
Management*

***Powering the United States Air Force!***